



Effects of nutrient enrichment in stream ecosystems in the upper Snake River basin, Idaho

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In a nutshell:

- 1. Macrophytes matter**
- 2. Sediment-bound nutrients matter**
- 3. Getting the limiting nutrient right matters**
- 4. Integrating biomonitoring with experimental approaches was more informative than either alone**

In cooperation with:

**U.S. Environmental Protection Agency
Idaho State University**



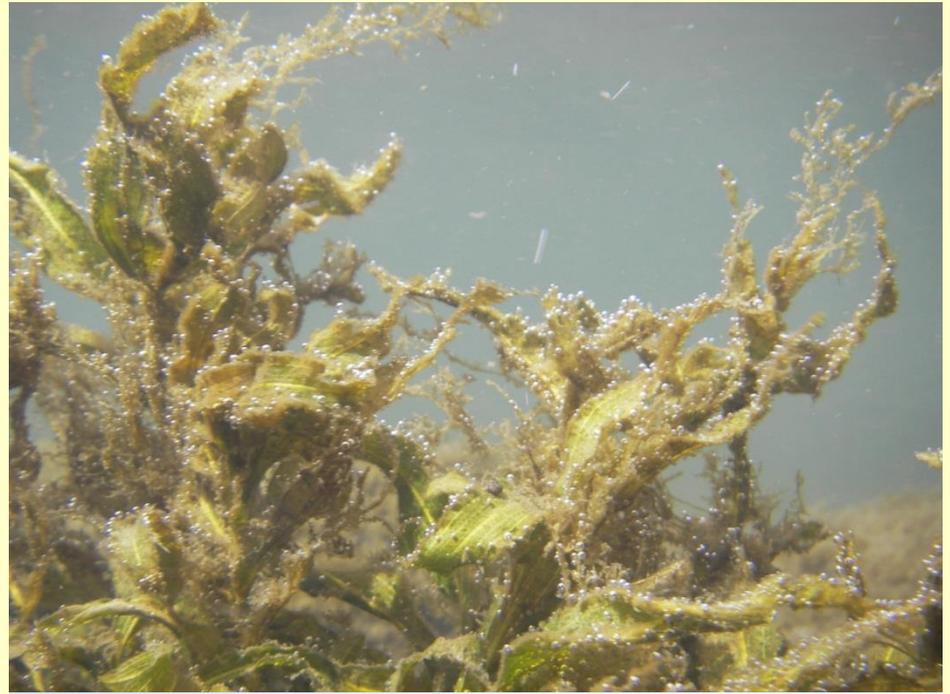
**U.S. Department of the Interior
U.S. Geological Survey**



1. Macrophytes matter



Productivity of streams may be more related to rooted plants than periphyton

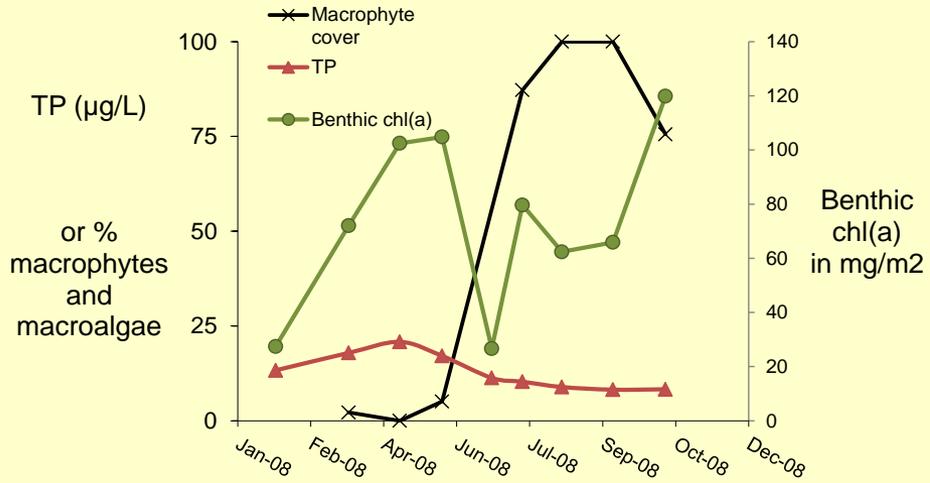


Macrophytes matter



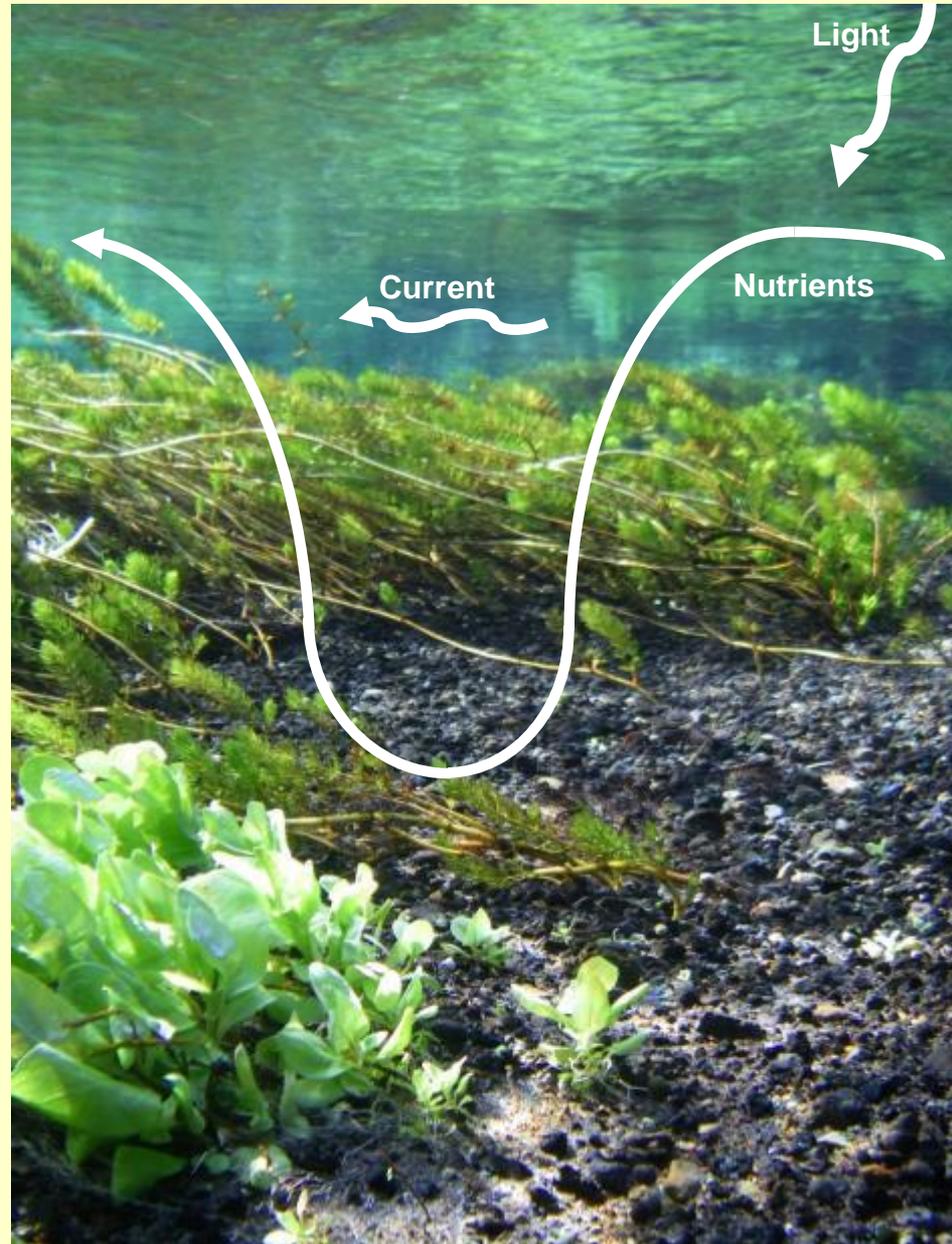
Macrophytes can confound periphyton based assessments

Stalker Creek, Idaho Upper Snake River basin



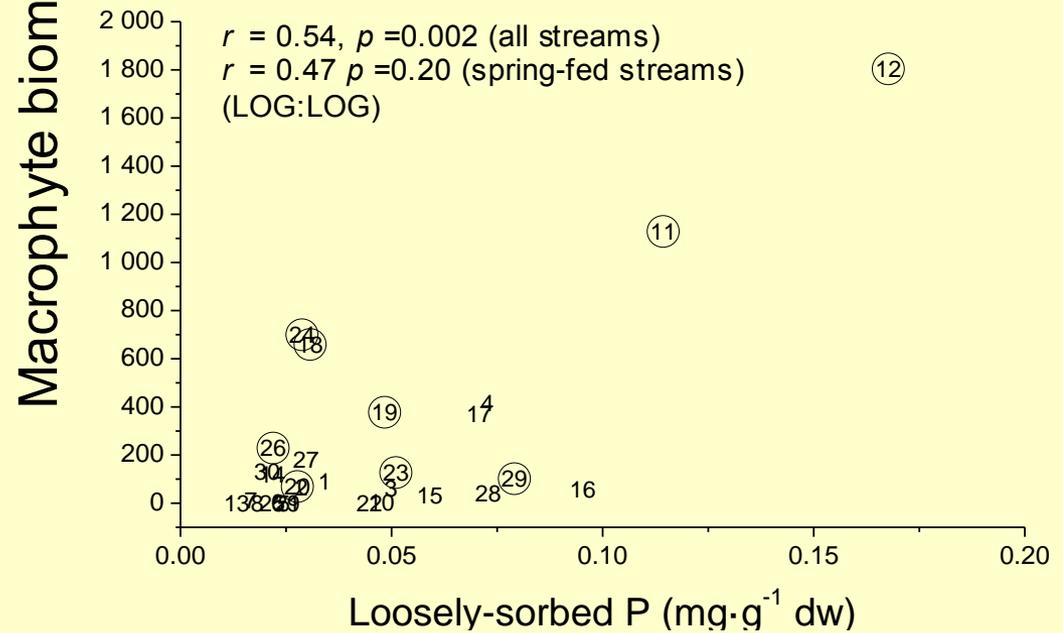
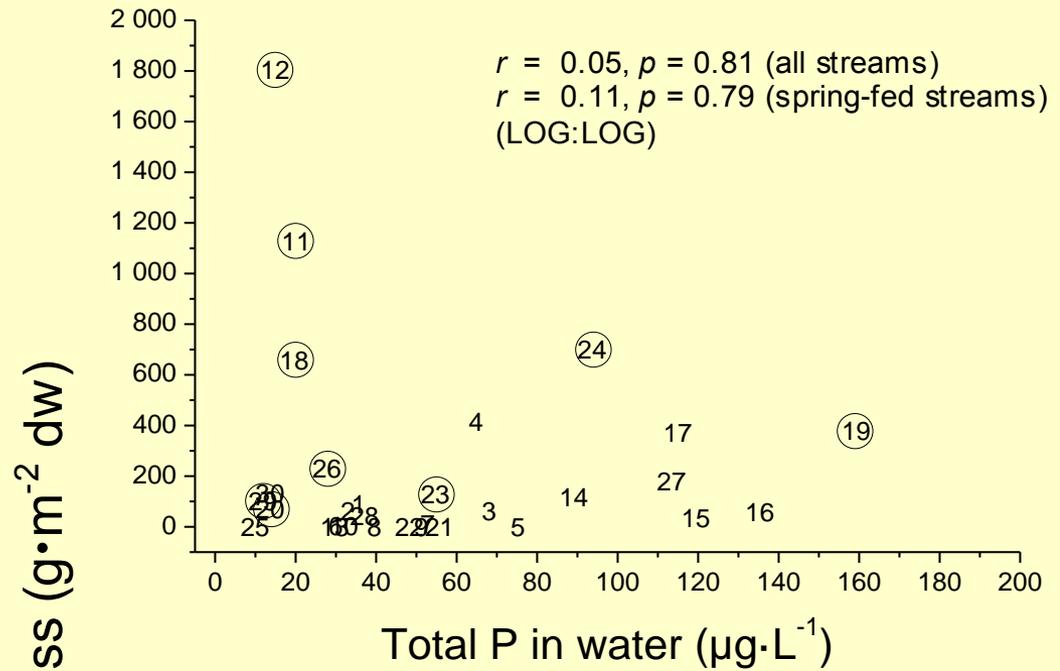
2. Sediment nutrients matter:

- Sediment is the primary source of P to macrophytes



Mebane, C.A., N.S. Simon, and T.R. Maret. 2014. Linking nutrient enrichment and streamflow to macrophytes in agricultural streams. *Hydrobiologia*. 722: 143-158

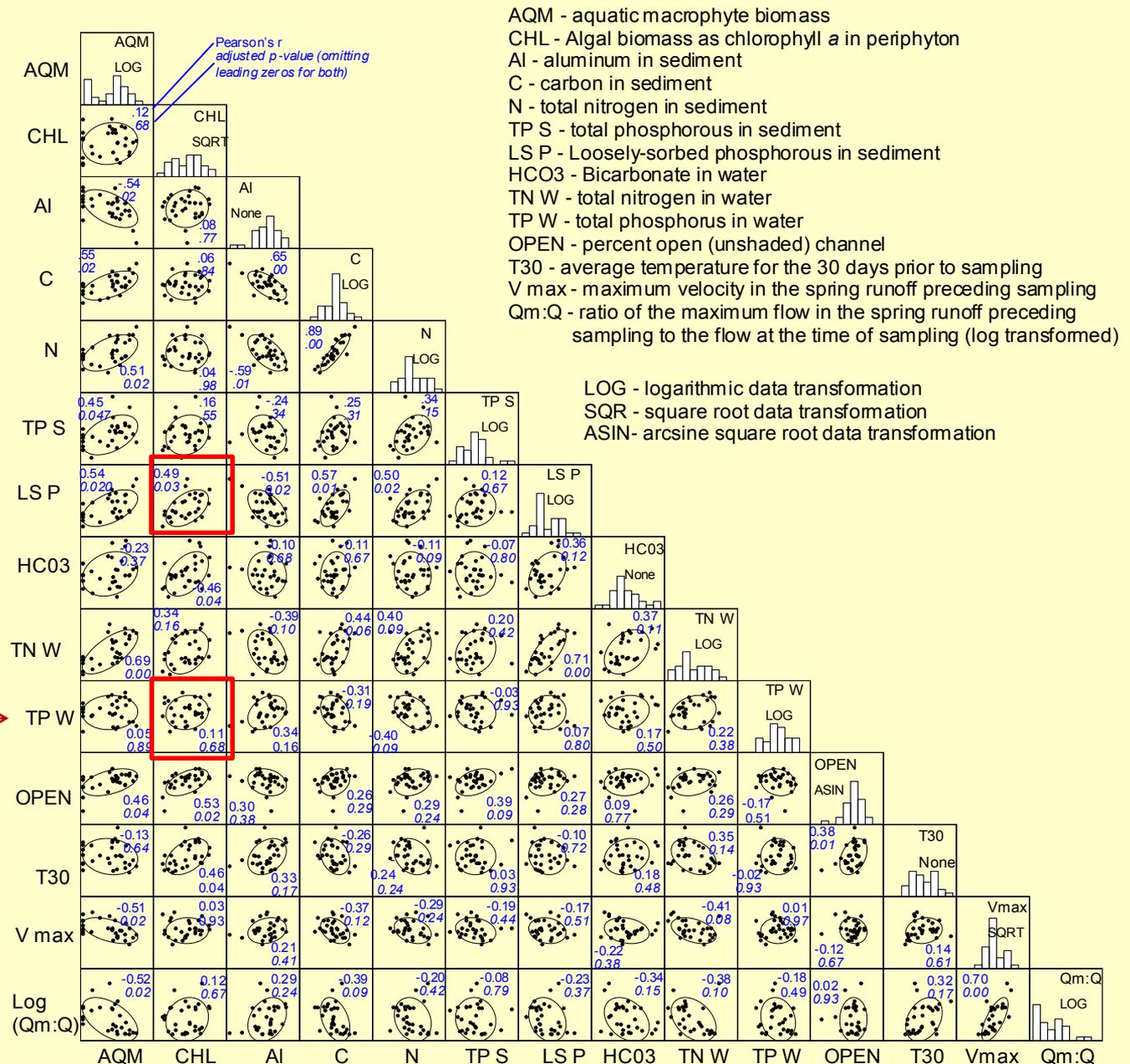
Sediment nutrients matter



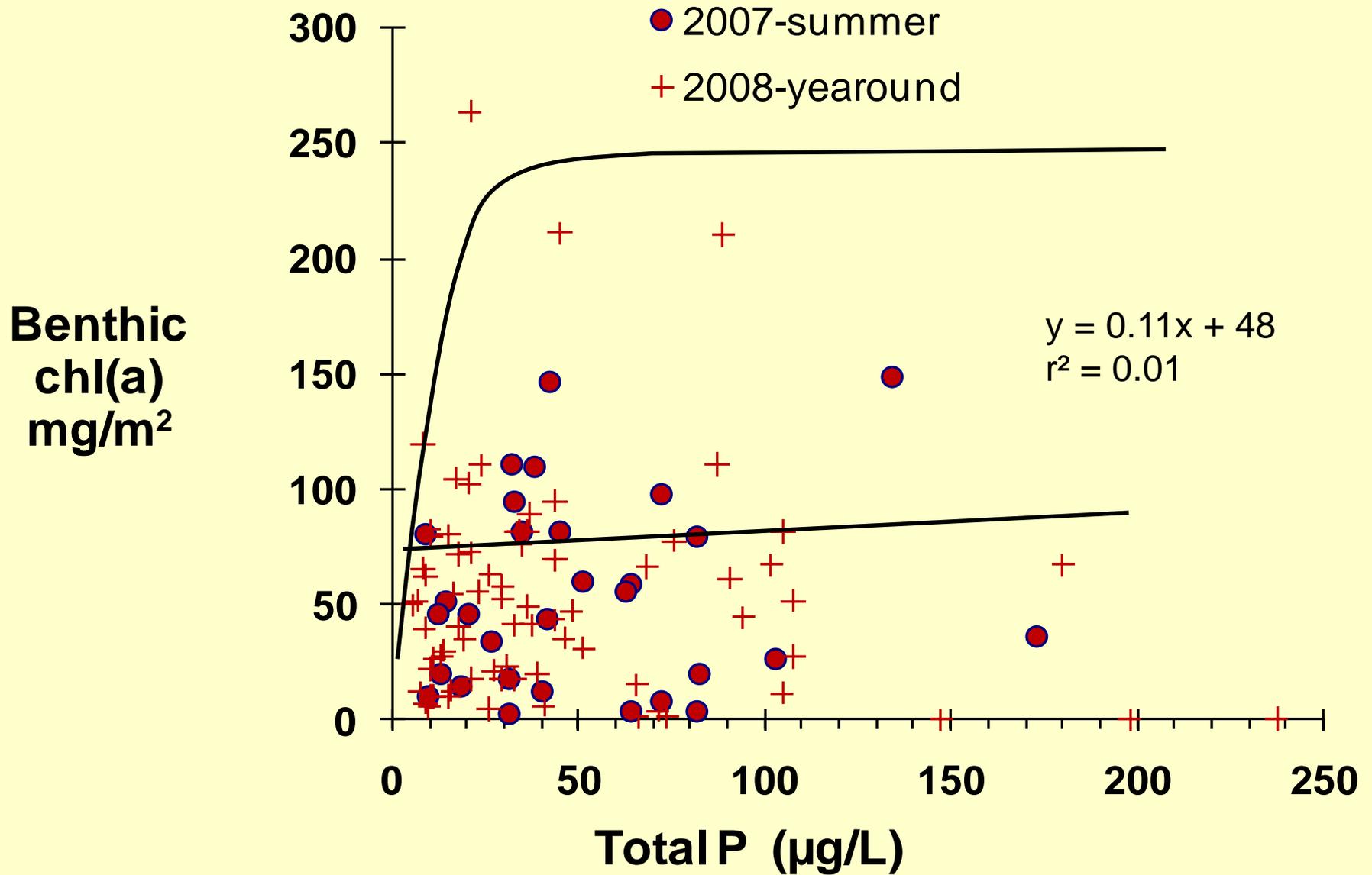
Sediment nutrients matter for periphyton too:

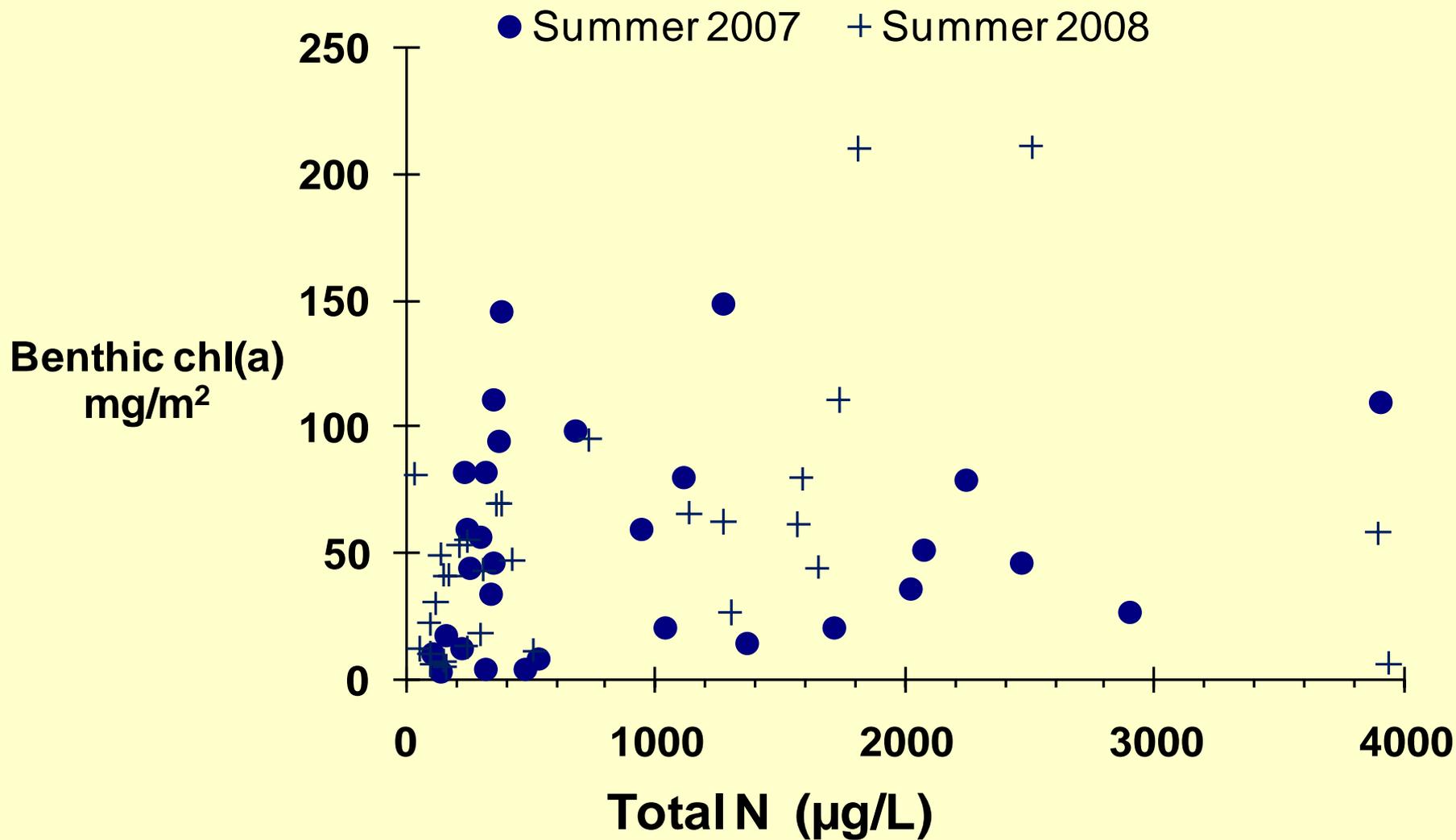
Loosely-sorbed P in sediment →

→ Total P in water

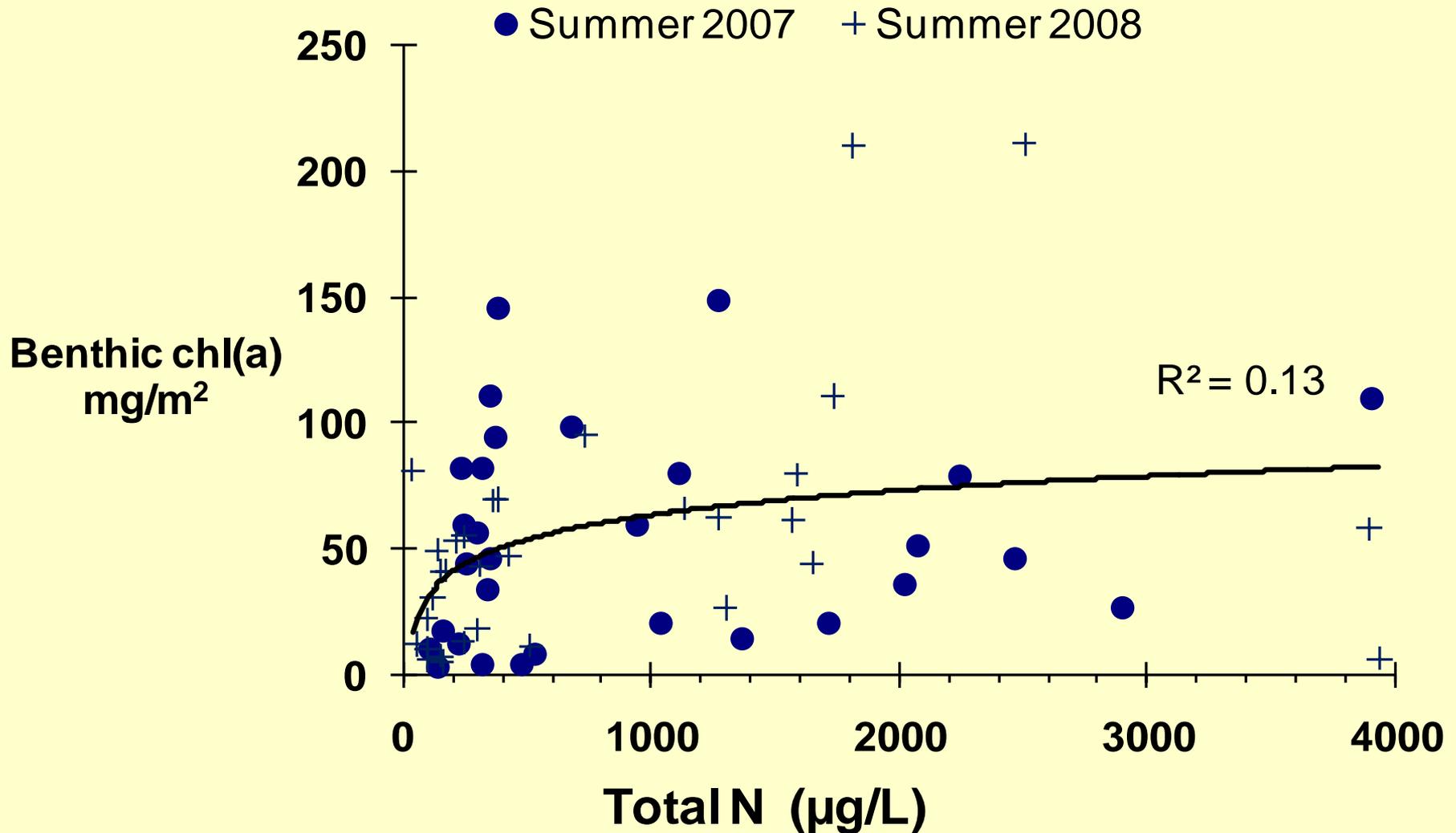


3. The limiting nutrient matters





Might correlations be poor because we're trying to relate algae biomass to the wrong limiting nutrient?

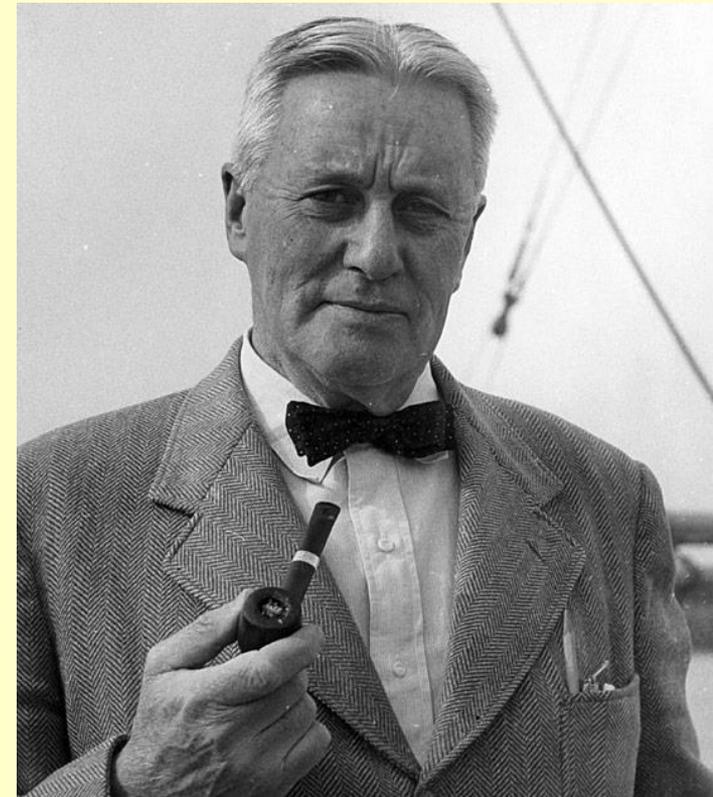


Concepts of limiting nutrients: Liebig's Law and Redfield's Ratios

- Redfield noticed that the ratio of N to P in marine phytoplankton is usually 16:1
- Apply Liebig's and Redfield's concepts to water, if N:P ratio is >16 , suggests N is in excess relative to P, therefore P is limiting
- In freshwaters, N:P ratios are usually >16 , and P is commonly assumed to be limiting



- Much debate since: is algae in freshwater streams limited by total amounts of nutrients, ratios or both?



4. Integrating field and experimental information

Experimental control



Suzanne Pargee, GEI

Single-species, *Selenastrum* green-algae laboratory tests

Multiple-species periphyton and duckweed microcosm



Chris Mebane, USGS

In situ nutrient diffusing substrate tests



Chris Mebane, USGS

Field studies



Terry Maret, USGS

Environmental relevance



Limitation Experiments: Low N stream

**Total P ~ 20 – 35 $\mu\text{g/L}$ (0.020
to 0.035 mg/L)**

**Total N ~ 40 to 400 $\mu\text{g/L}$
(0.04 to 0.4 mg/L)**

Big Cottonwood Creek

**Pristine rangeland
watershed: no
diversions, roads,
cows, or motorized
access**



Low P stream

Total P ~ 0.007 to 0.015 mg/L
(7 to 15 $\mu\text{g/L}$)

Total N ~ 1.0 mg/L (1000 $\mu\text{g/L}$)

- **Stalker Creek**

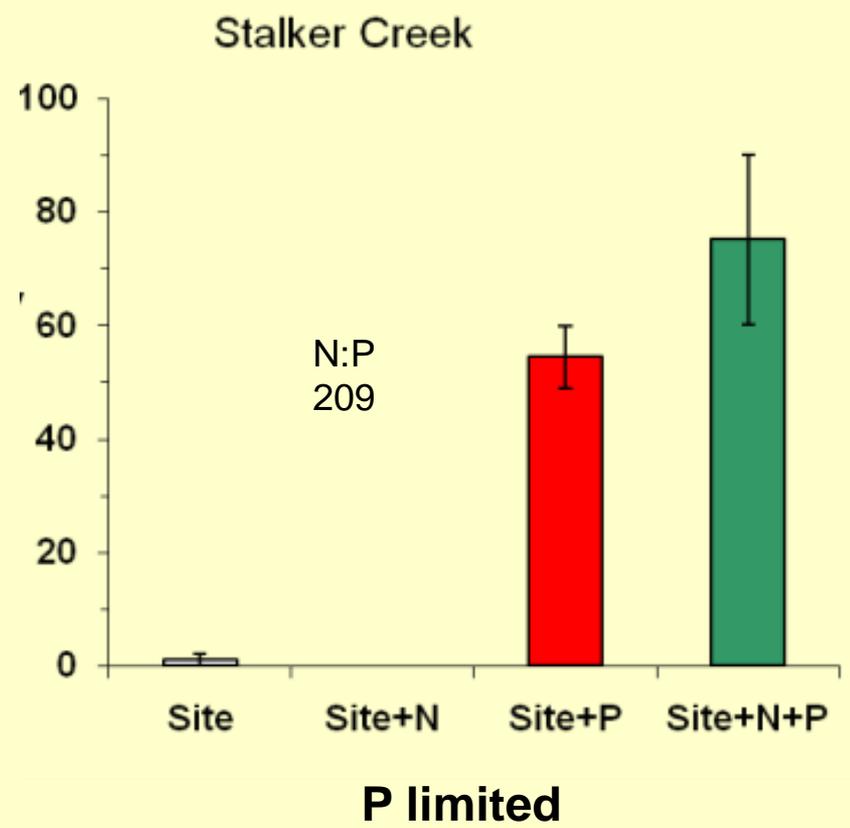
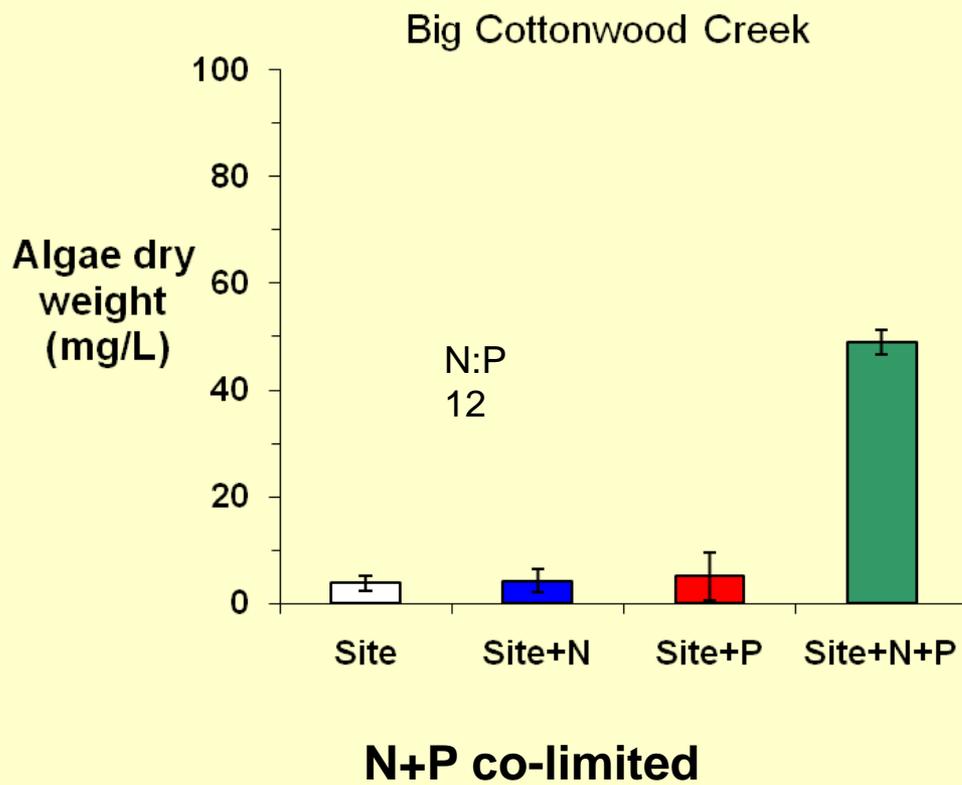
Few overt disturbances;
located on The Nature
Conservancy's Silver Creek
Preserve



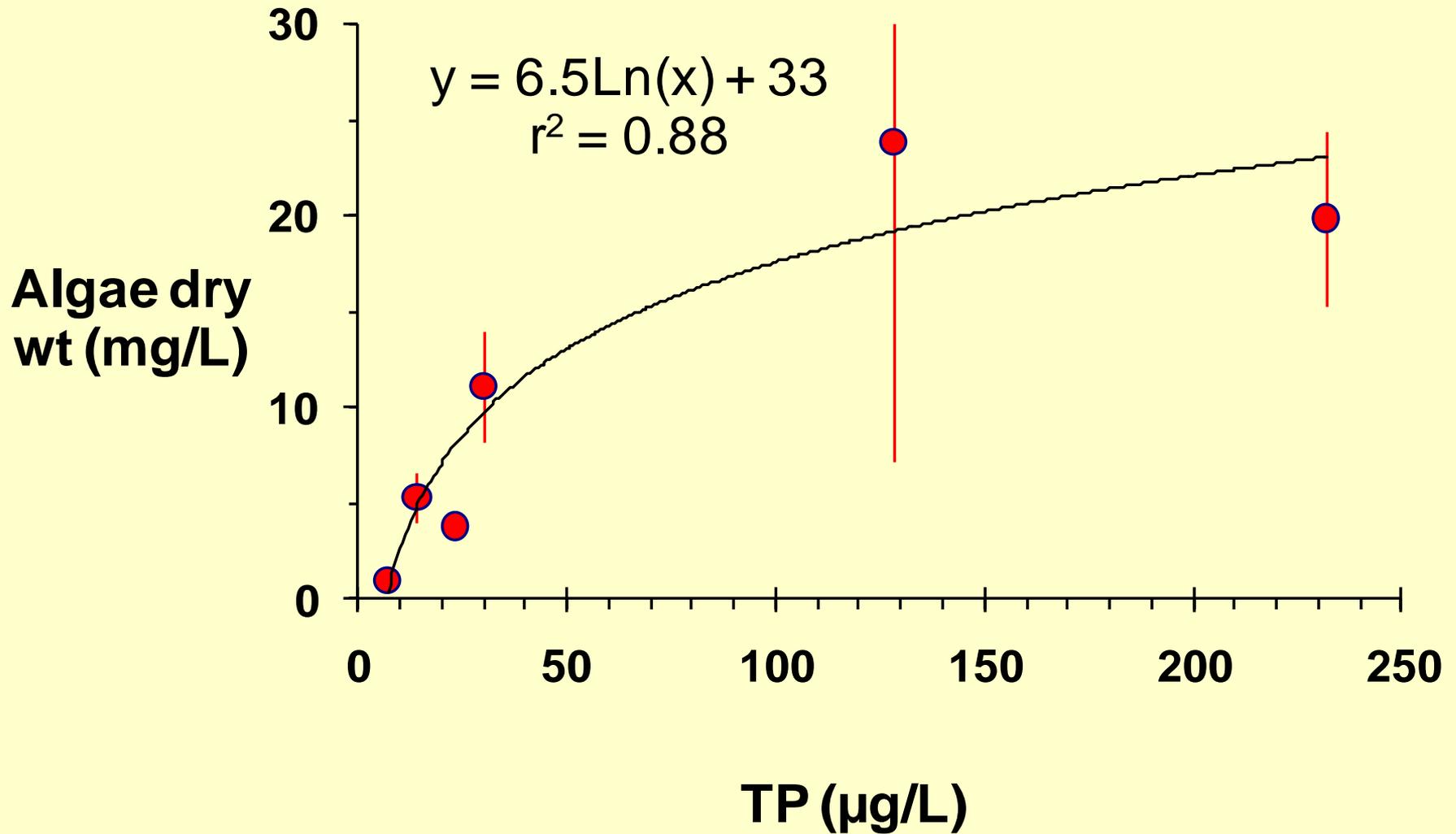
Sestonic green algal nutrient limitation assays

- Variation on EPA's whole effluent test (WET)
- Green algae
Pseudokirchneriella subcapitata (formerly *Selenastrum capricornutum*)
- Site water spiked with N, P or both
- 12-14 days test duration



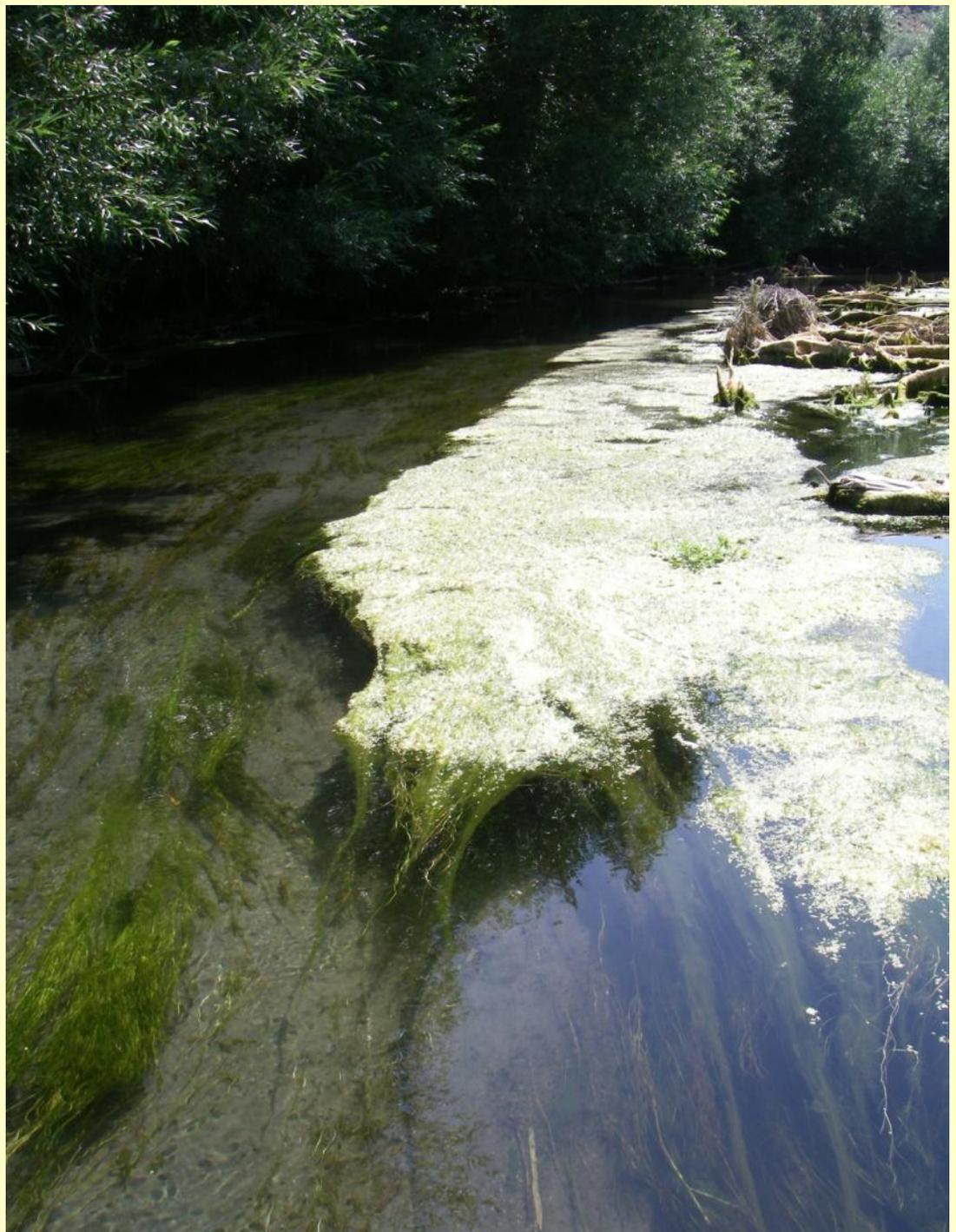


Green algae growth in ambient site water
(no nutrient additions)



**Stepping up from single
species test to a mixed
periphyton-macrophyte
nutrient limitation
experiment:**

**duckweed and
epiphytes**







Periphyton response: Epiphytic algae community was introduced with the duckweed

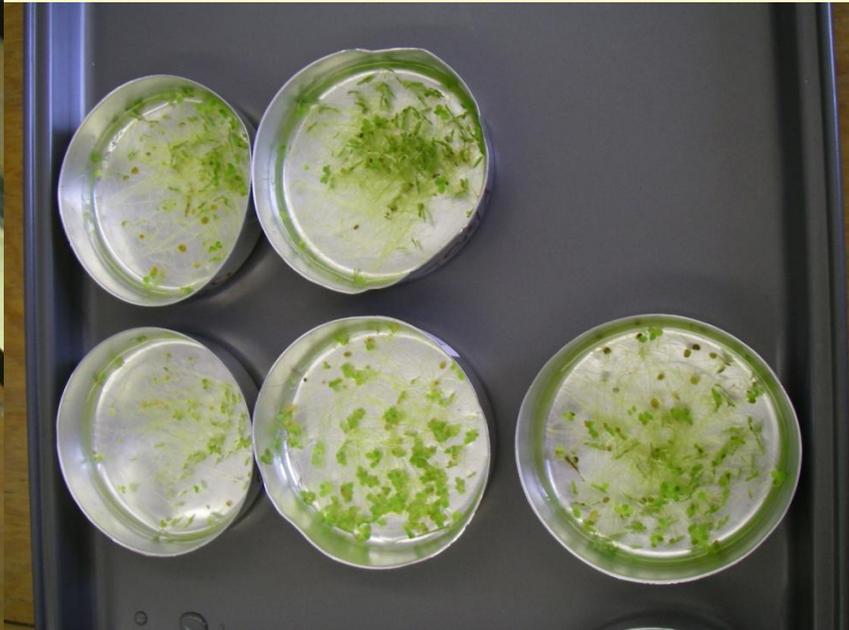




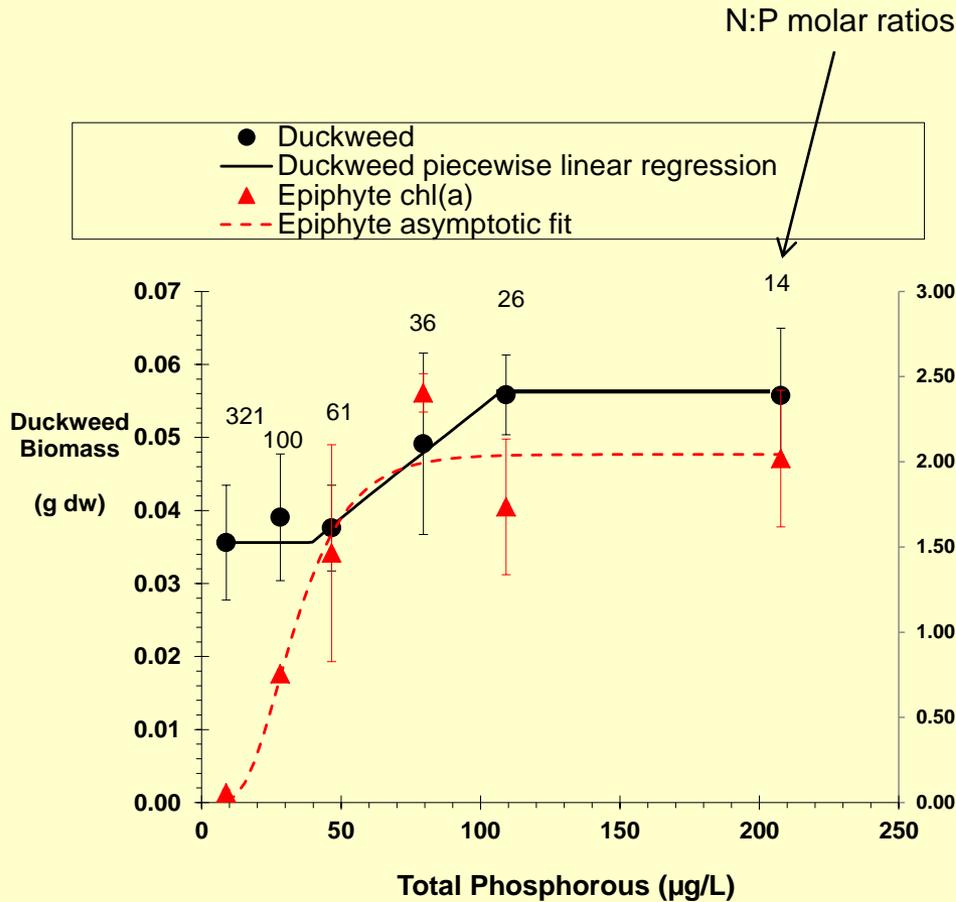


Ray, A.M., C.A. Mebane, F. Raben, K.M. Irvine, and A.M. Marcarelli. 2014. Evaluation of a combined macrophyte–epiphyte bioassay for assessing nutrient enrichment in the Portneuf River, Idaho, USA. *Environmental Monitoring and Assessment*.

<http://dx.doi.org/10.1007/s10661-014-3682-0>



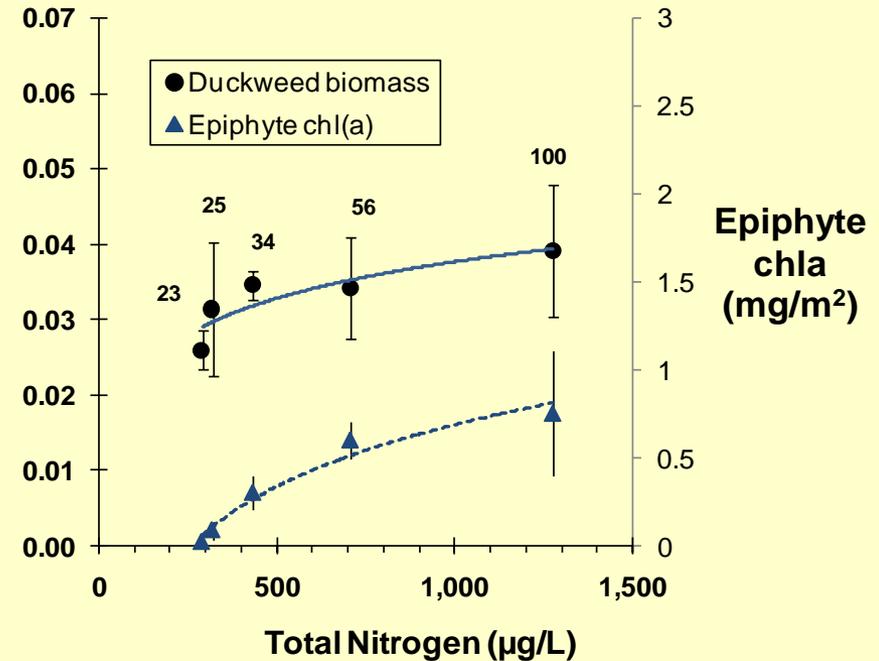
Less growth with N, but adding N still increased duckweed and algae biomass even though P should have been limiting



Initial ambient TN 1277 µg/L all treatments

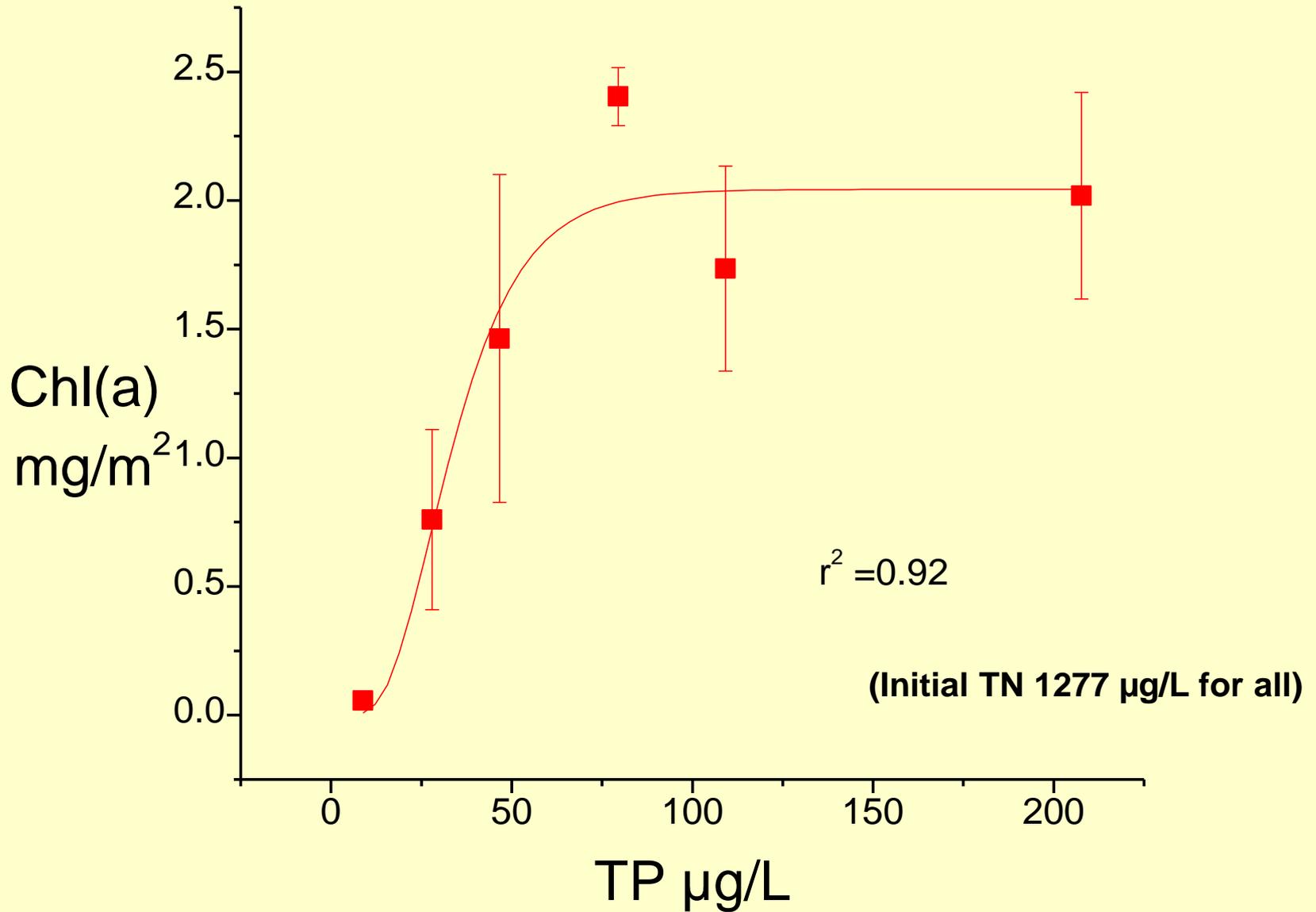
$y(\text{epiphyte chl(a)}) = 0.51 \ln(x) + 0.69$ $R^2 = 0.96$

$y(\text{Duckweed}) = 0.0069 \ln(x) + 0.0376$ $R^2 = 0.7743$



Initial ambient TP 28 µg/L all treatments

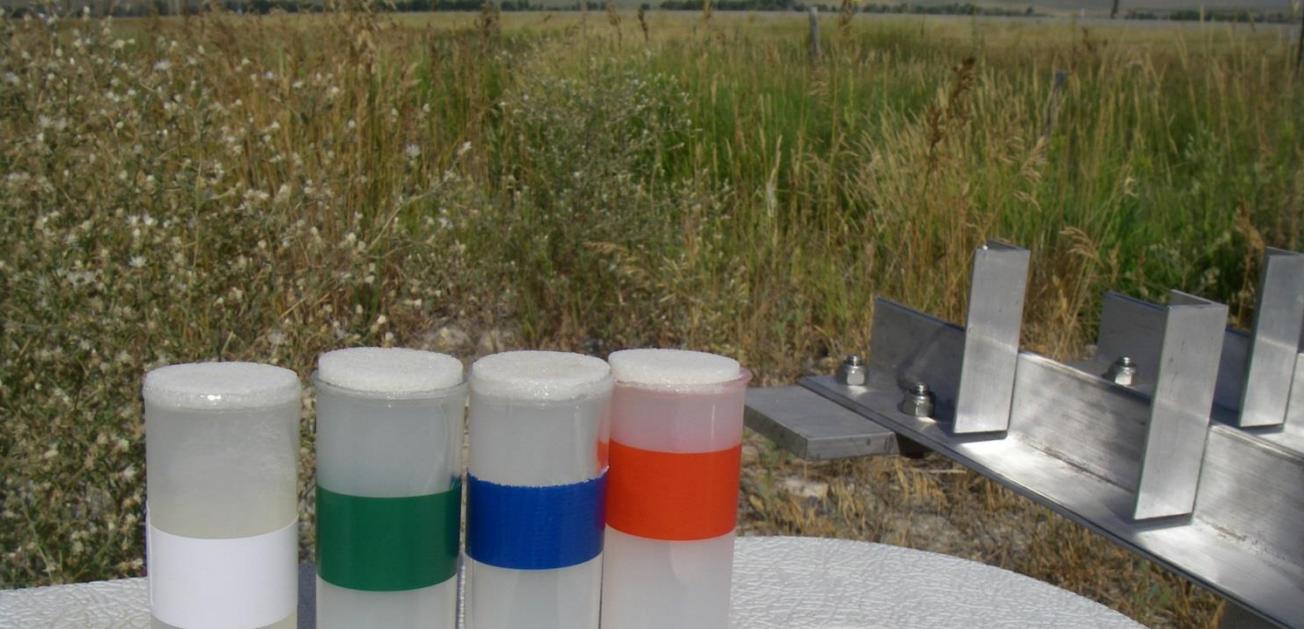
Periphyton appeared saturated with P at ~ 75 $\mu\text{g/L}$



In stream benthic periphyton limitation experiments with nutrient diffusing substrates



**Red – Phosphorus (P), Blue – Nitrogen (N), Green – N+P,
White - controls**







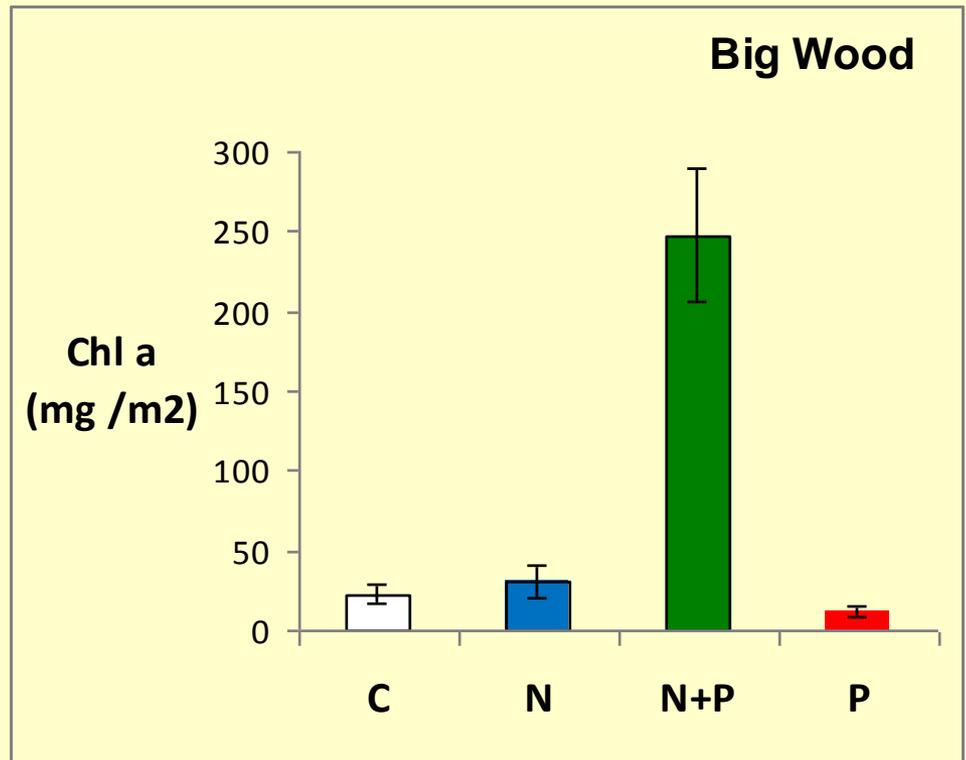
Big Wood River

N+P are co-limiting

TP: 7 – 10 $\mu\text{g/L}$

TN: 50 – 100 $\mu\text{g/L}$

N:P molar ratio: 15 – 22





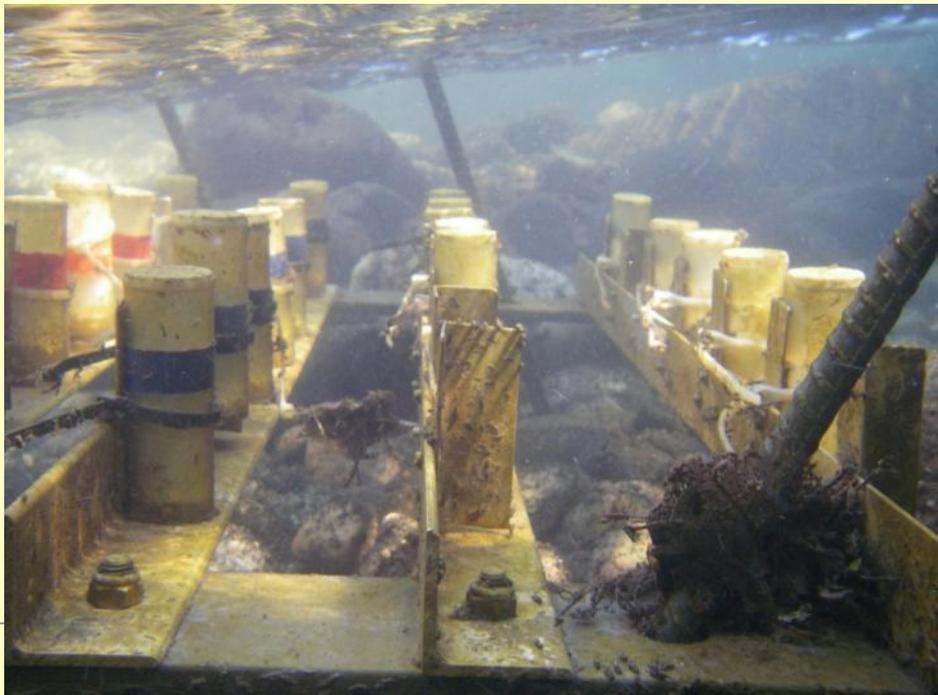
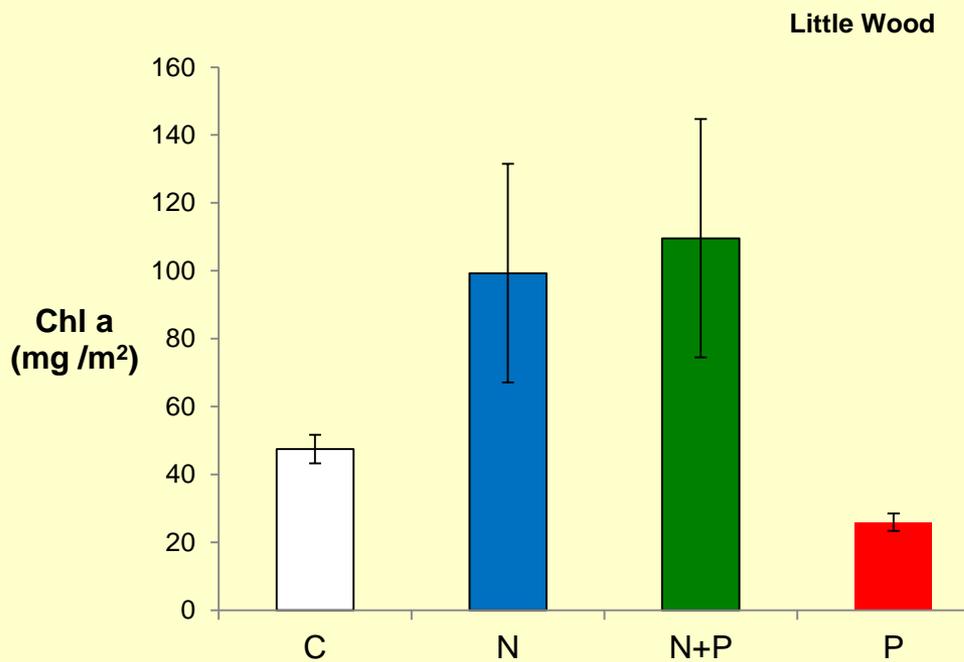
Little Wood River

Chla N limited

TP: 10 – 14 $\mu\text{g/L}$

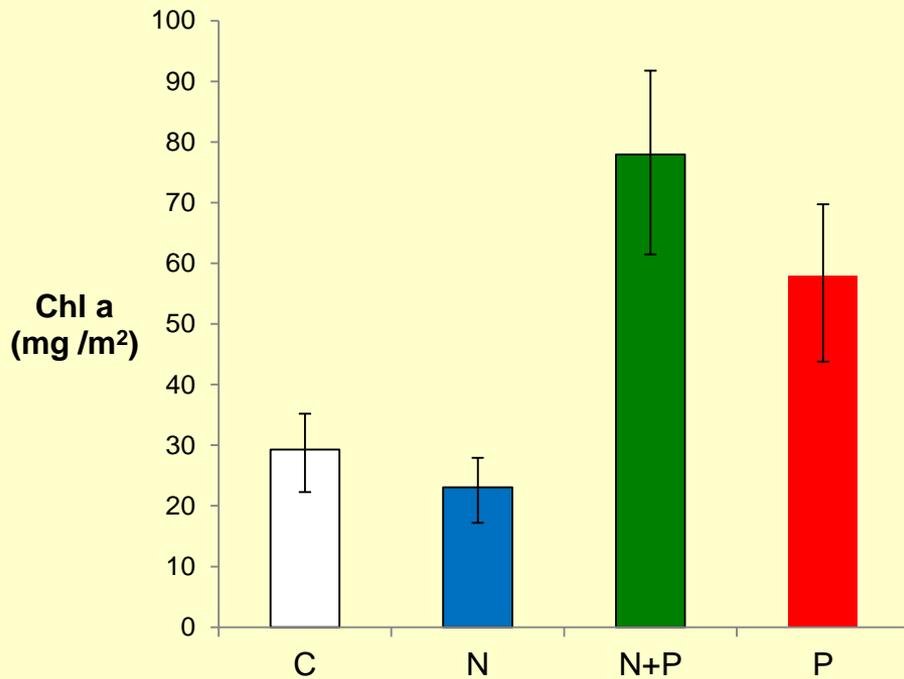
TN: 93 – 118 $\mu\text{g/L}$

N:P molar ratio: 14 – 20





Stalker



Stalker Creek

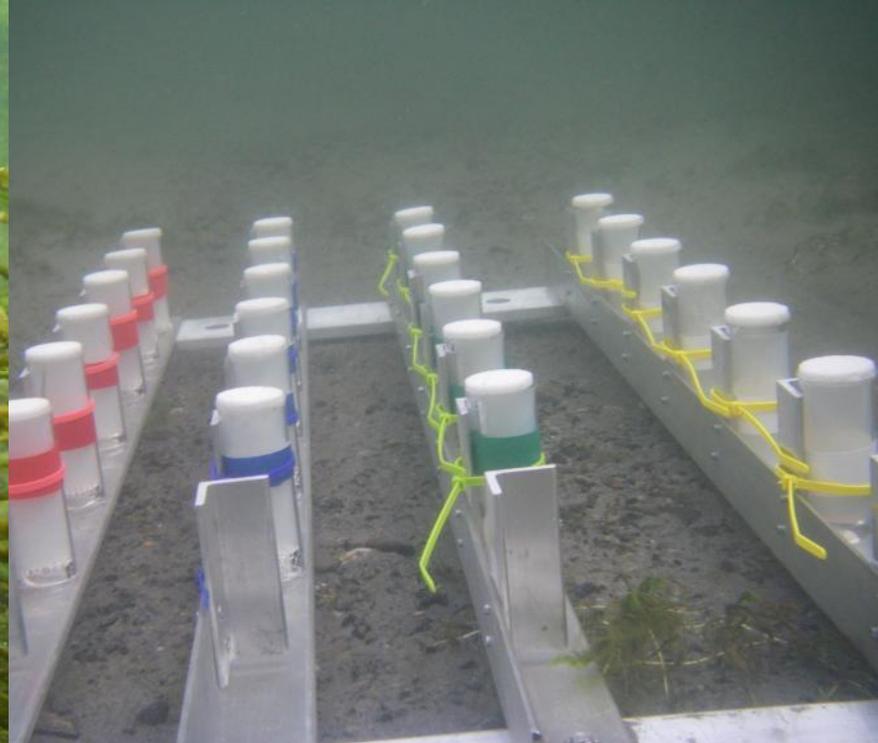
P limited

TP: 8 – 10 $\mu\text{g/L}$

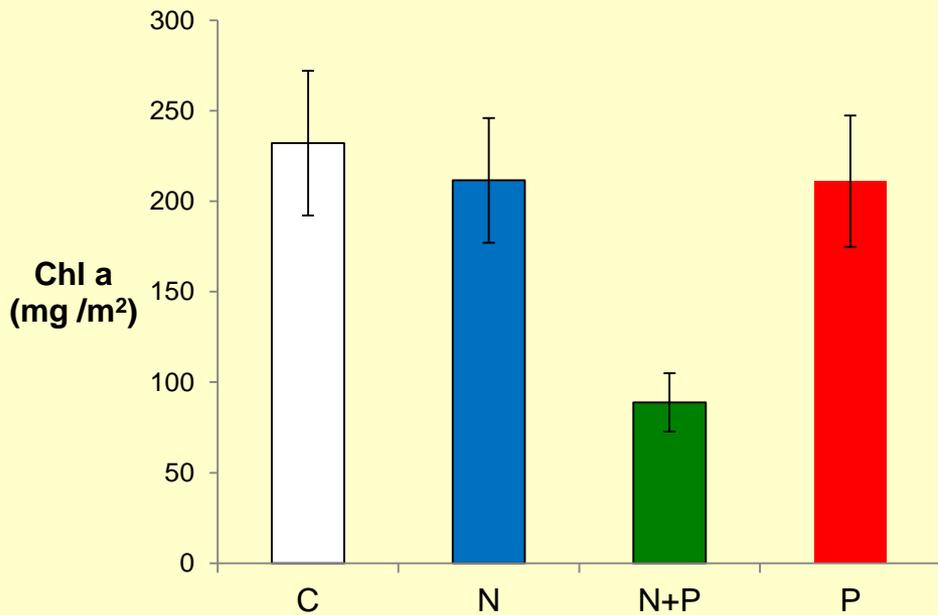
TN: 1130 – 590 $\mu\text{g/L}$

N:P molar ratio: 340- 305





Billingsley



Billingsley Creek

Periphyton are not limited by nutrients

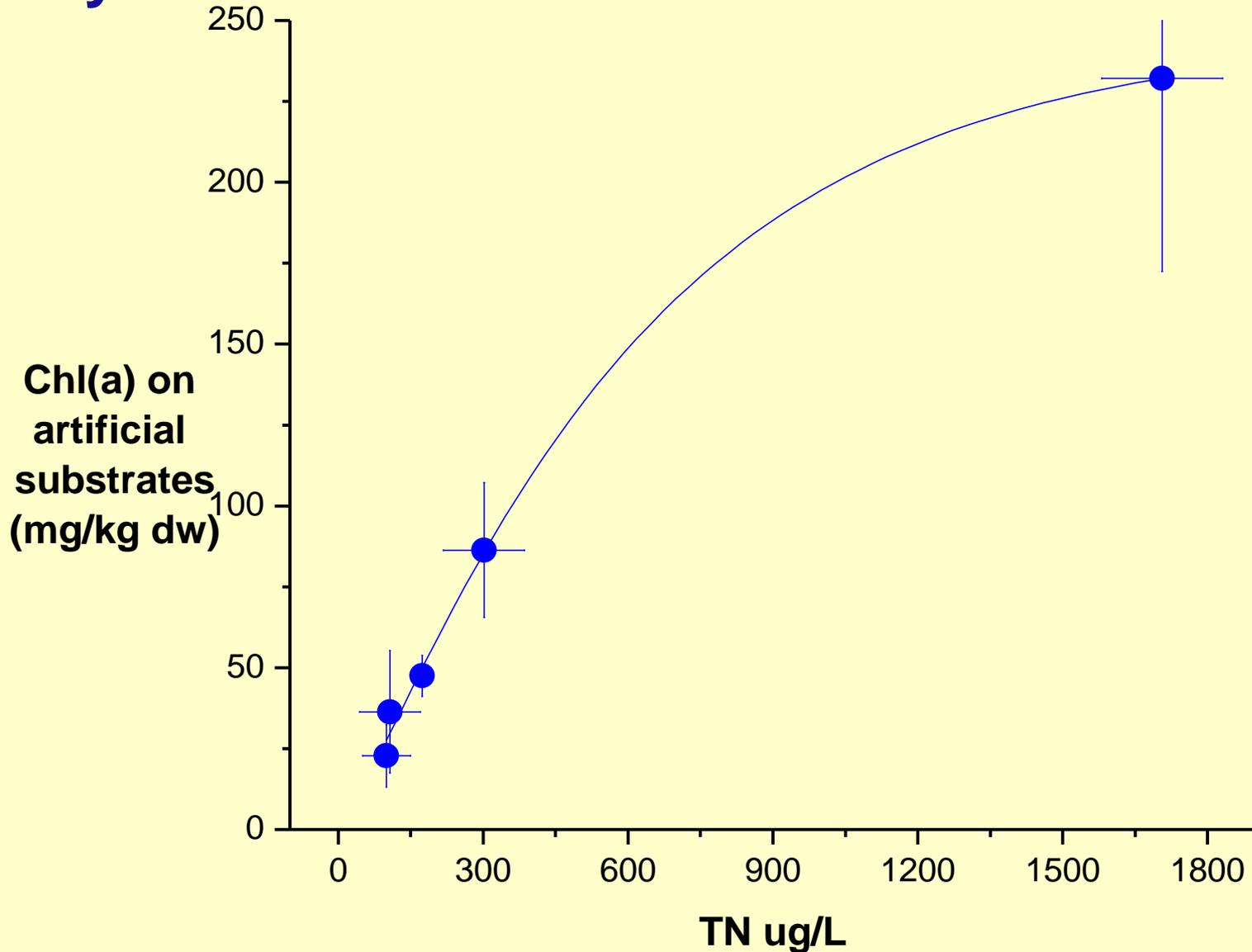
NP addition suppressed chl a

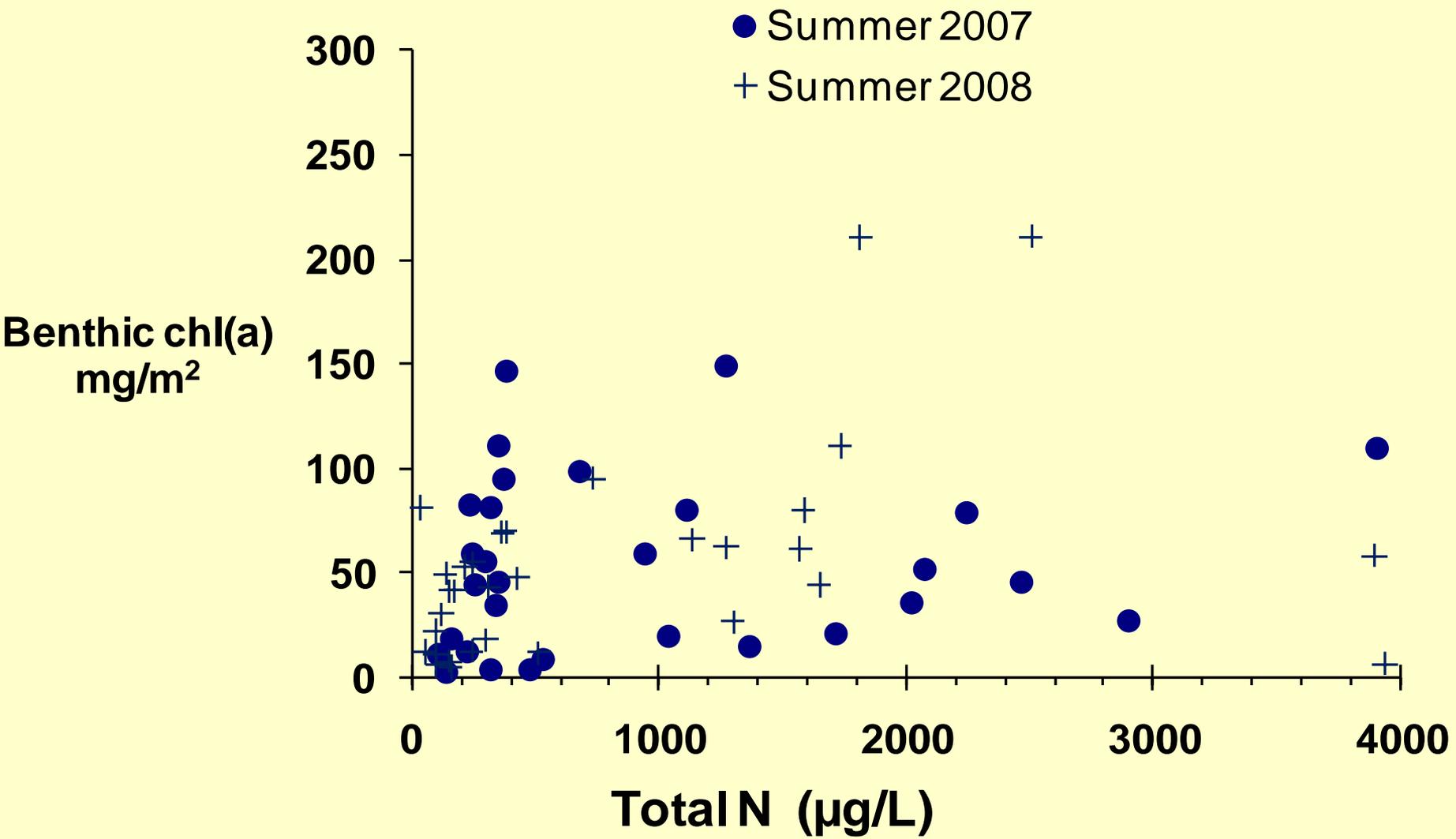
TP: 87 – 91 $\mu\text{g/L}$

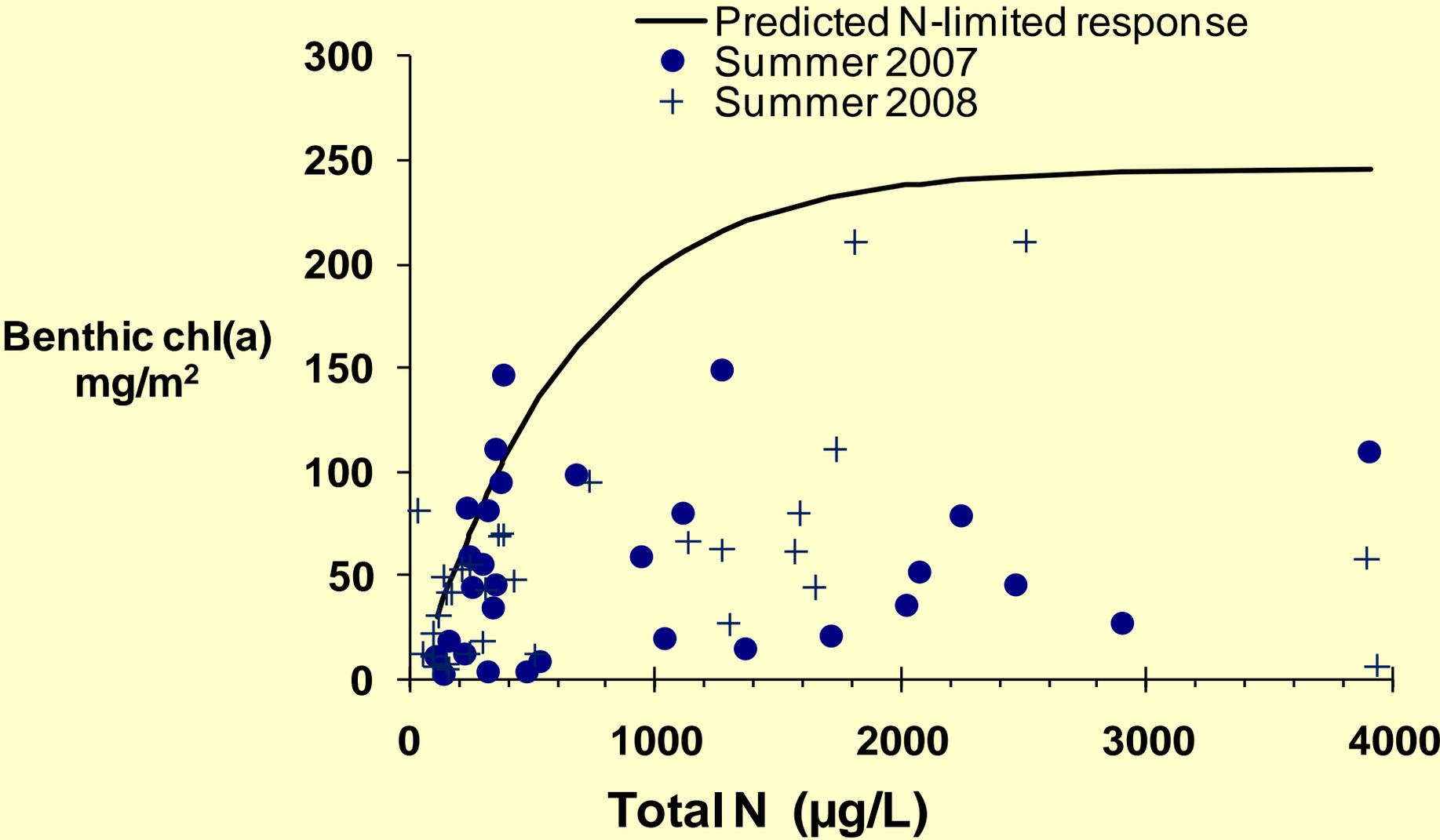
TN: 1570 – 1820 $\mu\text{g/L}$

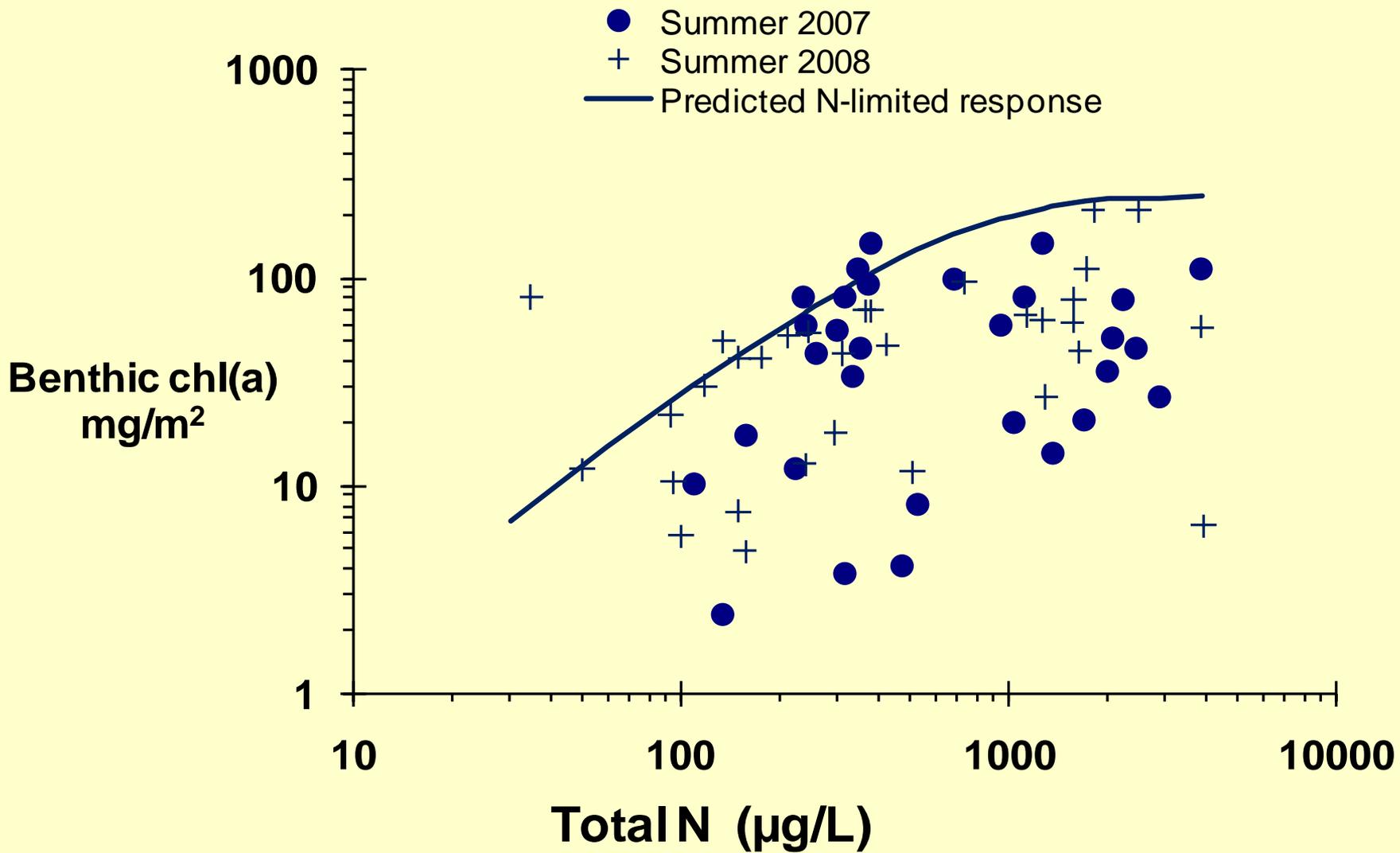
N:P molar ratio: 38 – 44

N and chlorophyll at N limited sites, 21-day accrual

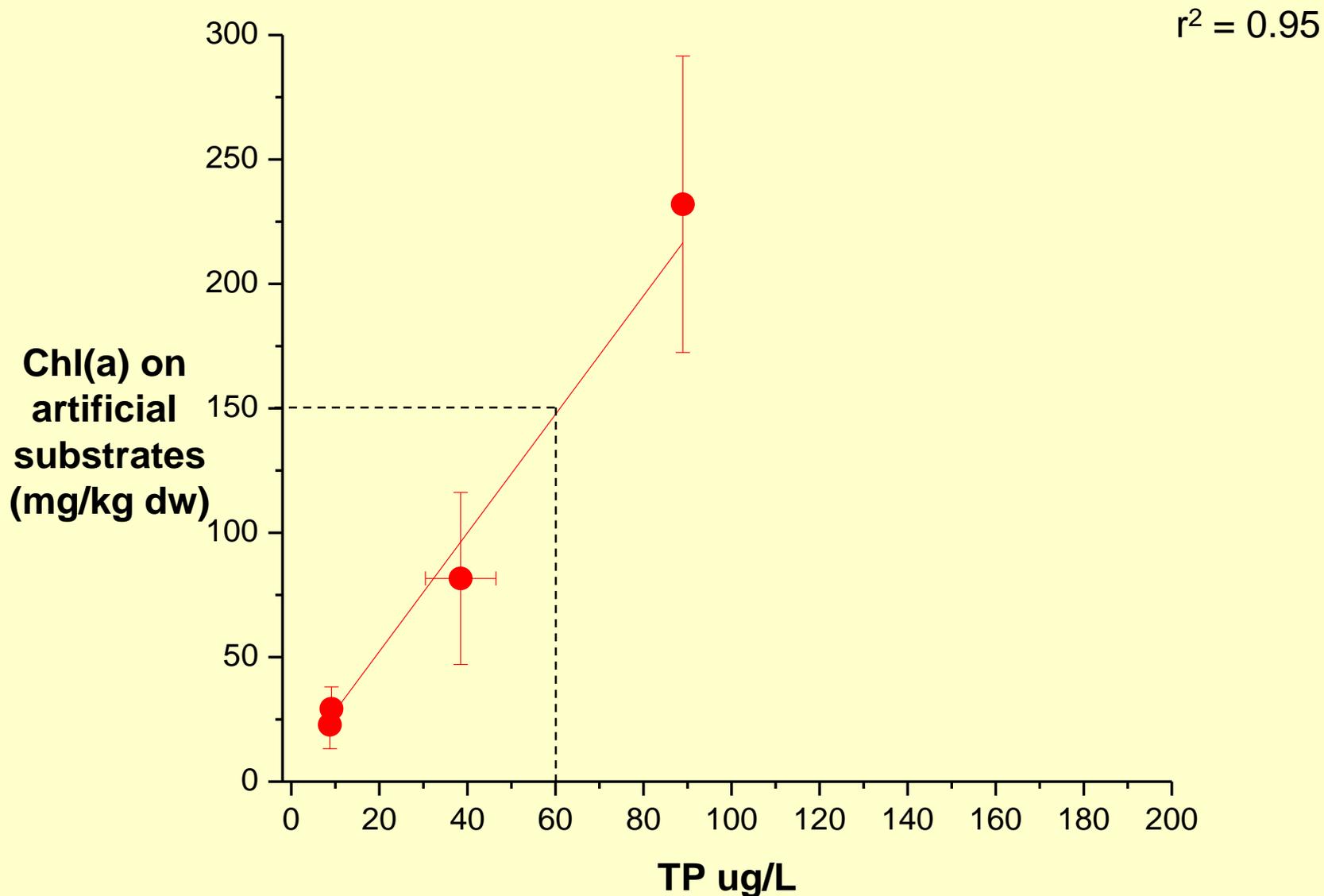




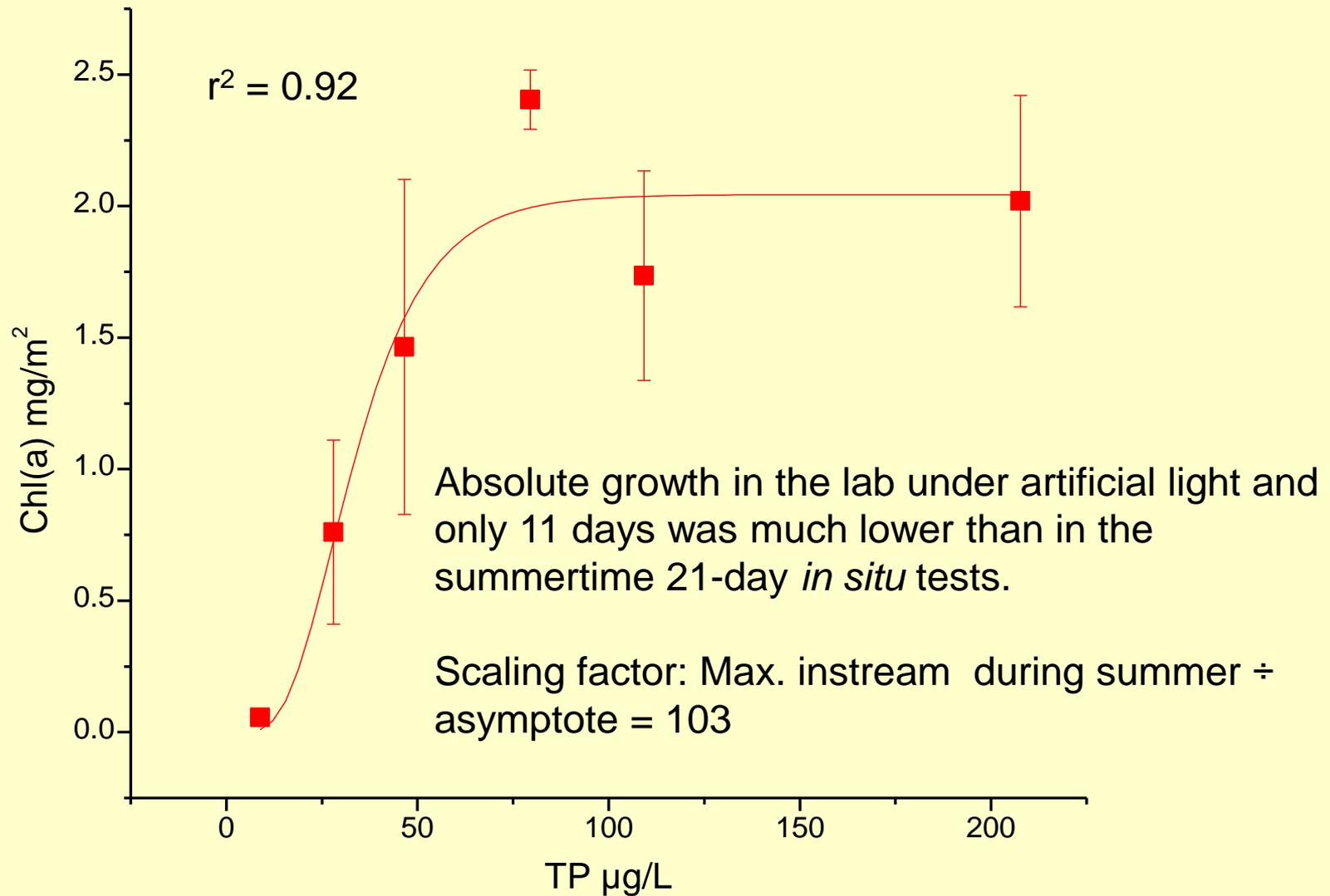


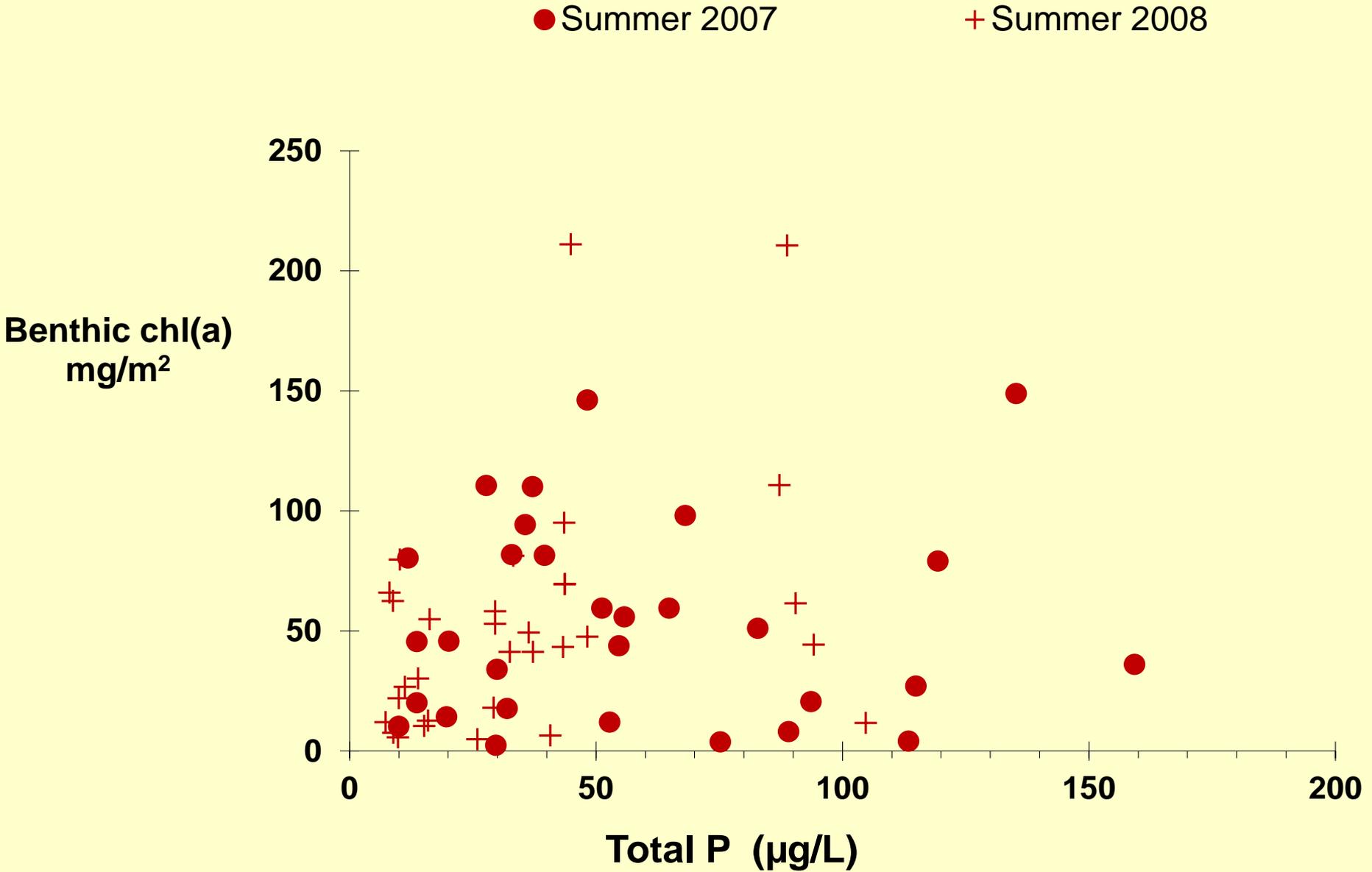


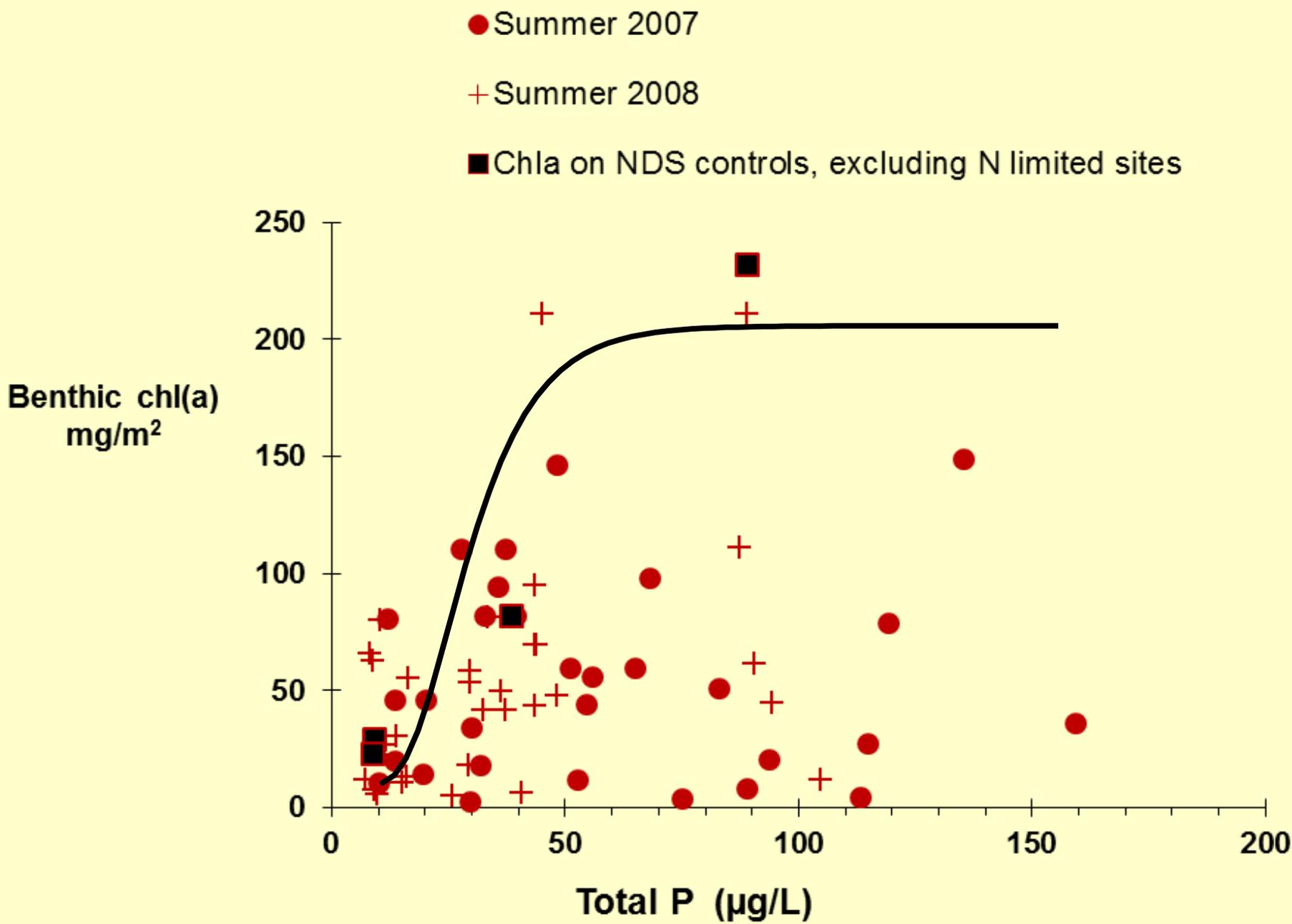
TP and chlorophyll at non-N limited sites, 21-day accrual

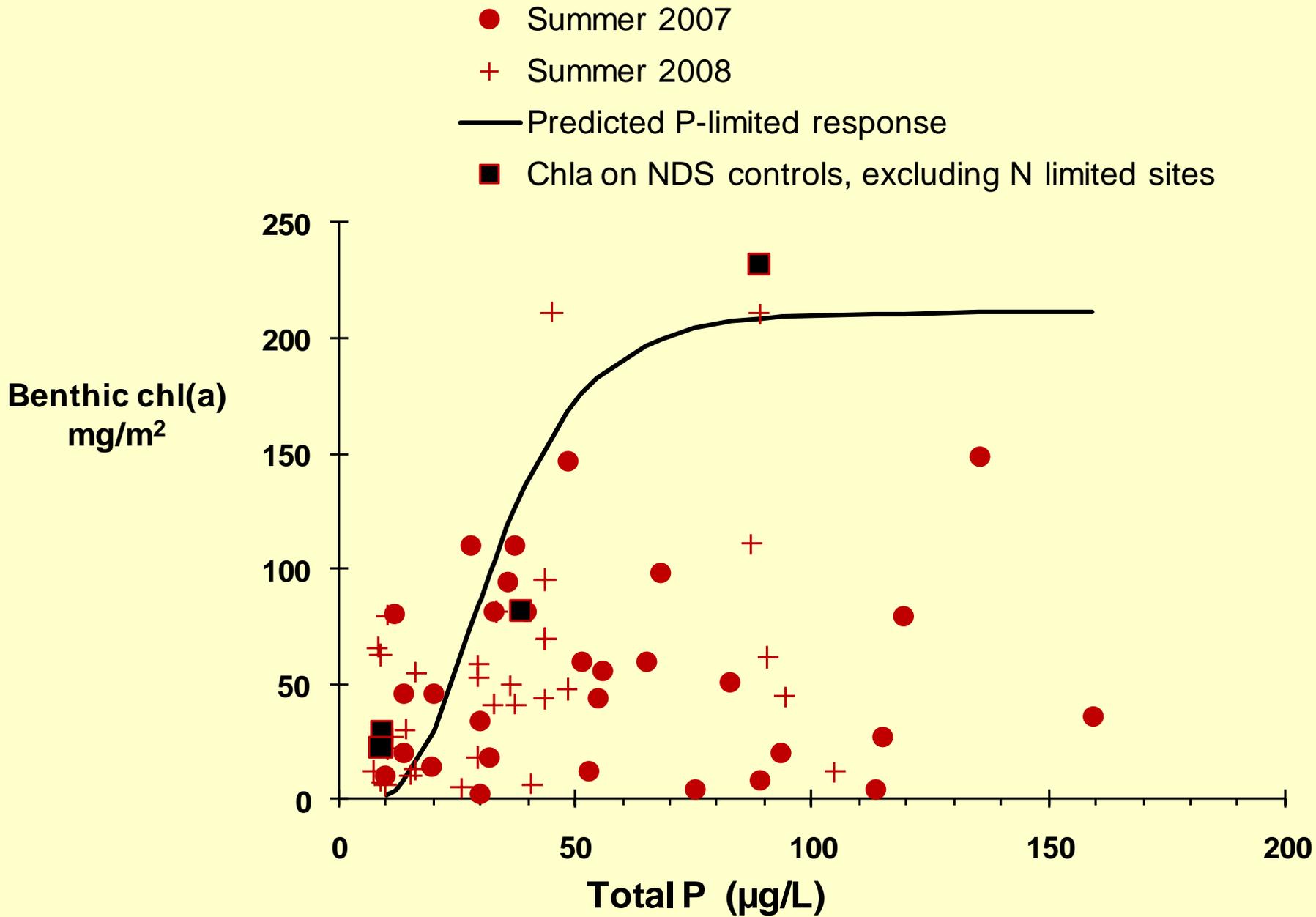


P and chlorophyll from the duckweed-epiphyte growth lab tests









Conclusions: Nutrient Limitation

1. Integrating field surveys with controlled manipulations was more informative than either alone
2. N limitation or co-limitation was most common
3. N:P ratios $>\approx 30$ generally indicated primary P limitation
4. With periphyton or green algae, P had no minimum response threshold
5. About 40 to 60 $\mu\text{g/L}$ TP and about 600 $\mu\text{g/L}$ TN corresponded with the 150 mg/kg “too-green” periphyton chlorophyll guideline
6. Uptake of N and P can confound relations between algae and nutrients.



Comments?

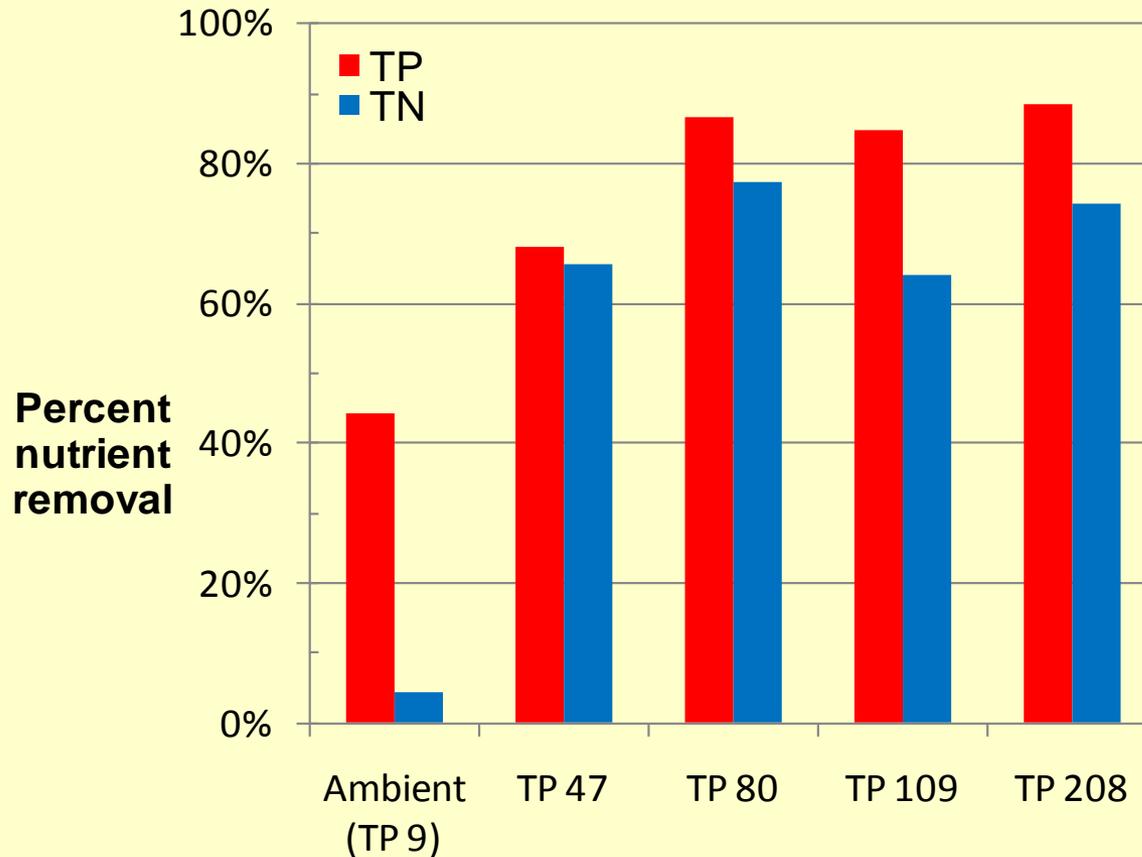


Slides for possible discussion explanations:

Up to 90% of the nutrients were removed by the plants over the 11 day test

Phosphorus enrichment test

Initial ambient total nitrogen 1277 $\mu\text{g/L}$ (all treatments, no amendments)



Initial Phosphorus Treatment Concentrations
in $\mu\text{g/L}$

Day 11



